

Effect of cloud fraction on near- cloud aerosol behavior based on MODIS and CALIPSO observations

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From Chapter 7 of IPCC AR5 report

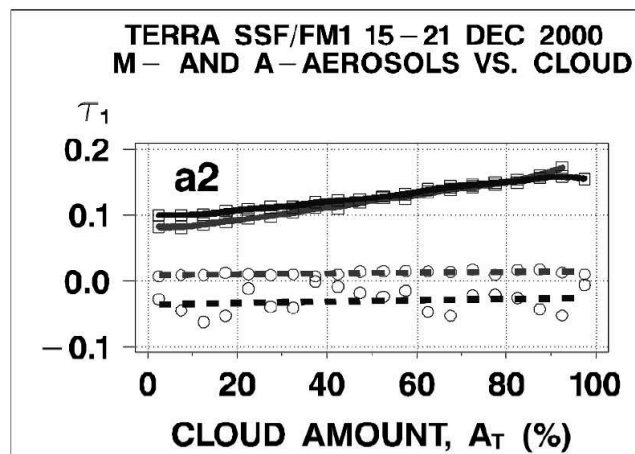
*... aerosol measured in the vicinity of clouds is **significantly different** than it would be were the cloud field, and its proximate cause (high humidity), not present. The latter results from **humidification effects** on aerosol optical properties, **contamination by undetectable cloud fragments** and **the remote effects of radiation** scattered by cloud edges on aerosol retrieval.*

What happens to aerosol in the vicinity of clouds?

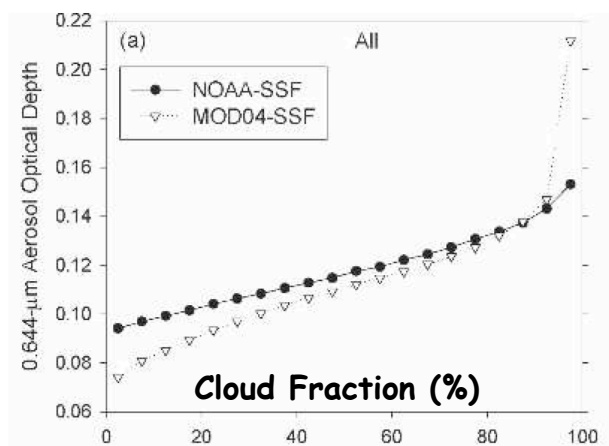
All observations show that aerosols seem to grow near clouds
or

(to be safer) "most satellite observations show a positive correlation between retrieved AOT and cloud cover", e.g.,

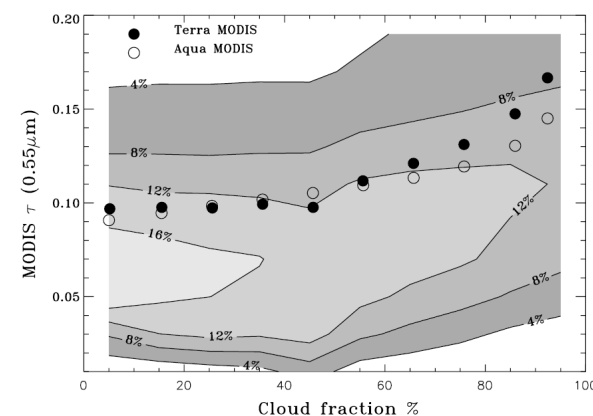
Chand et al. (2012) using MODIS data found a 25% enhancement in AOT between CF 0.1-0.2 and CF 0.8-0.9.



from Ignatov et al., 2005



from Loeb and Manalo-Smith, 2005



from Zhang et al., 2005

What happens to aerosol in the vicinity of clouds?

However, it is not clear yet how much growth comes from

- “real” microphysics, e.g.
 - increased hygroscopic aerosol particles
 - new particle production
 - other in-cloud processes.
- “artificial” effects, e.g.
 - cloud contamination (sub-pixel clouds)
 - extra illumination from clouds (a clear pixel in the vicinity of clouds)
 - sampling issue

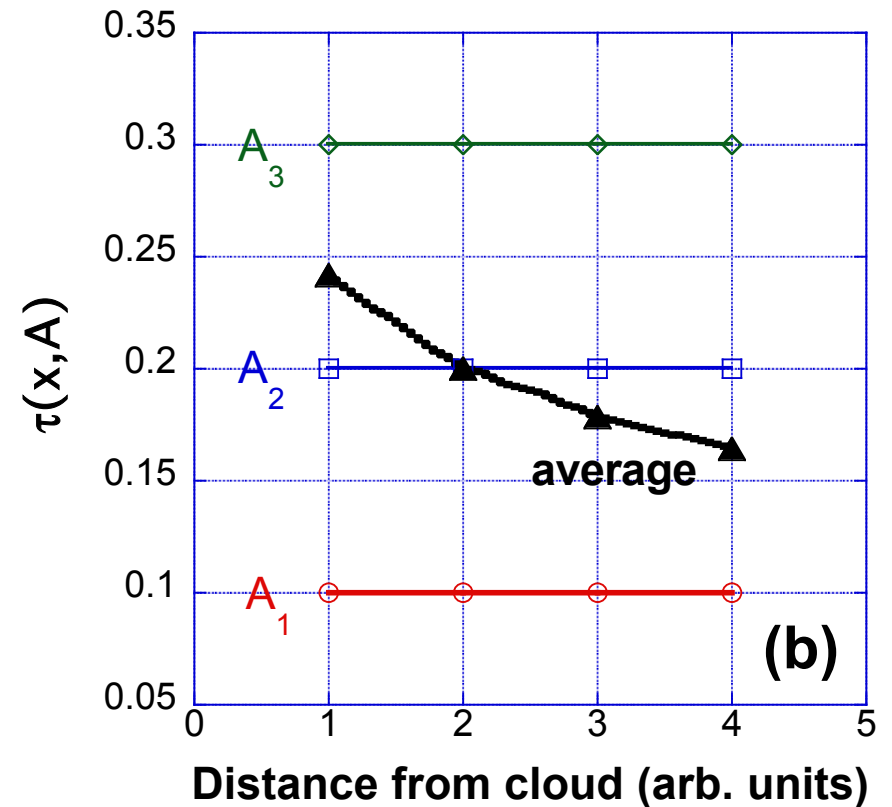
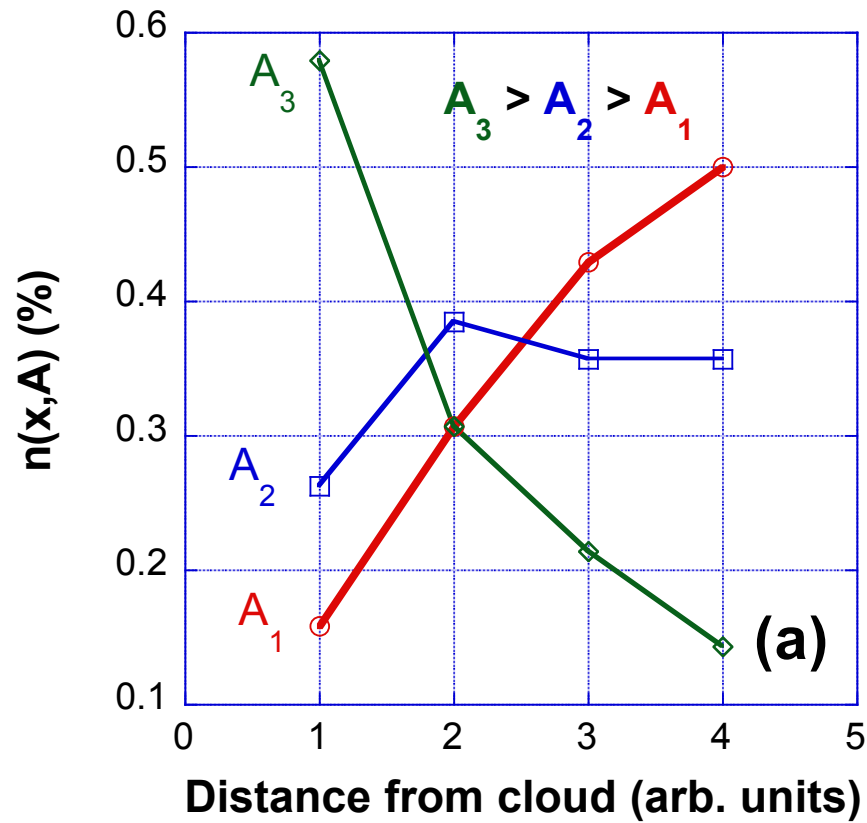
The “artificial” effects may significantly overestimate AOT.

Sampling Issue

Far-from-cloud aerosol statistics is dominated by data from scenes with lower CF (and thus lower AOT), while near-cloud aerosol statistics is dominated by data from scenes with higher CF (and thus higher AOT).

Schematic illustration

Here A is cloud fraction and x is distance to cloud

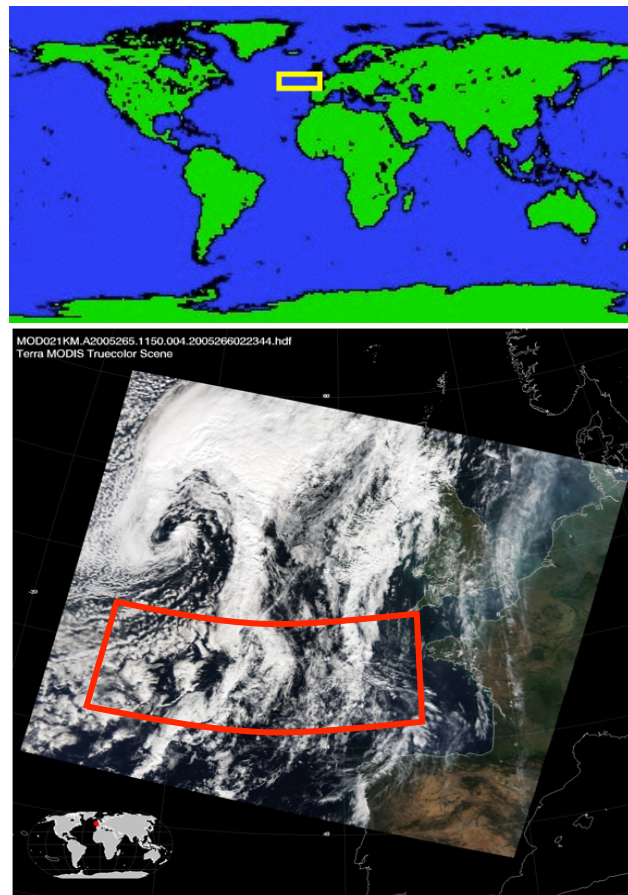


Schematic illustration of the potential effect of sampling on the averaged AOT as a function of distance to cloud and cloud cover.

What is the true statistical behavior of aerosol properties as a function of cloud fraction and distance to clouds ?

MODIS

Ocean Color Aerosol Product



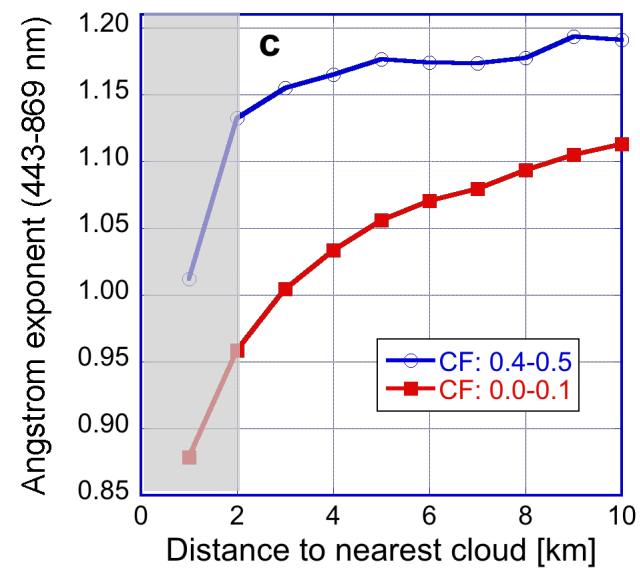
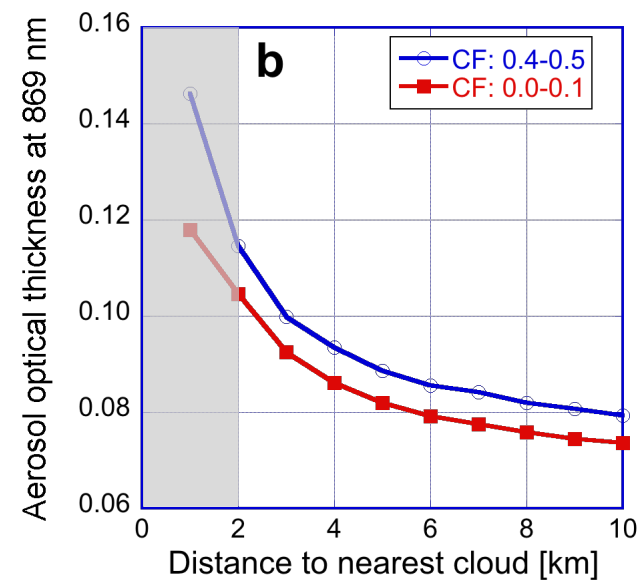
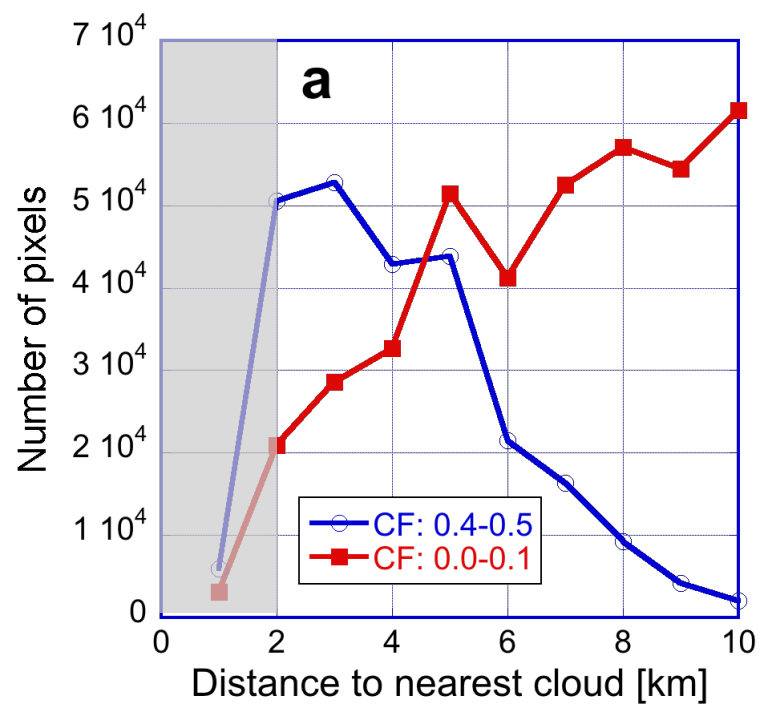
2 Sep. weeks for 10 years (2002-2011) of MODIS obs.: southwest of UK

STRAYLIGHT flag

*Stray light from adjacent, bright sources such as cloud edges is known to contribute to error in MODIS ocean color retrievals. In MODIS/Aqua Reprocessing 1.1 (2005), pixels within a **7x5-pixel region** around bright pixels were flagged as straylight and masked in Level-3.*

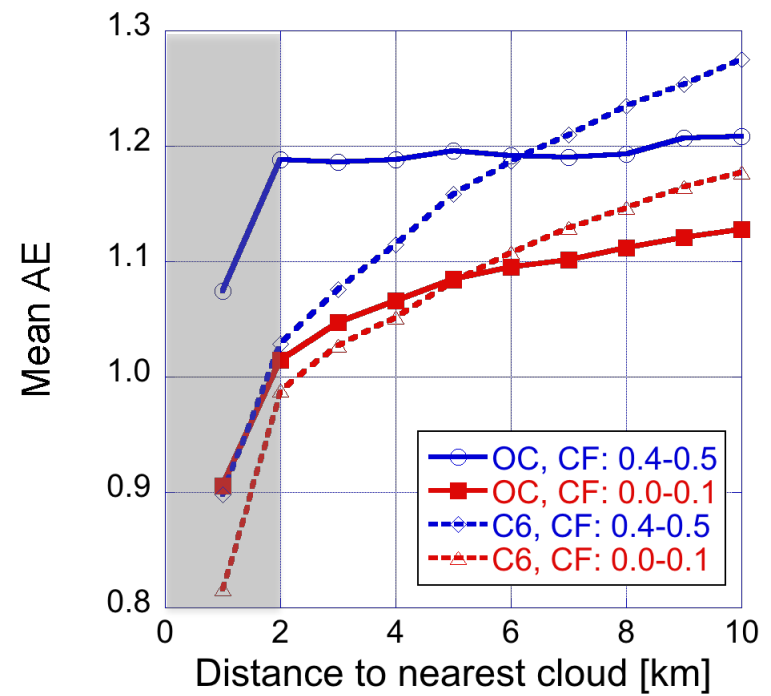
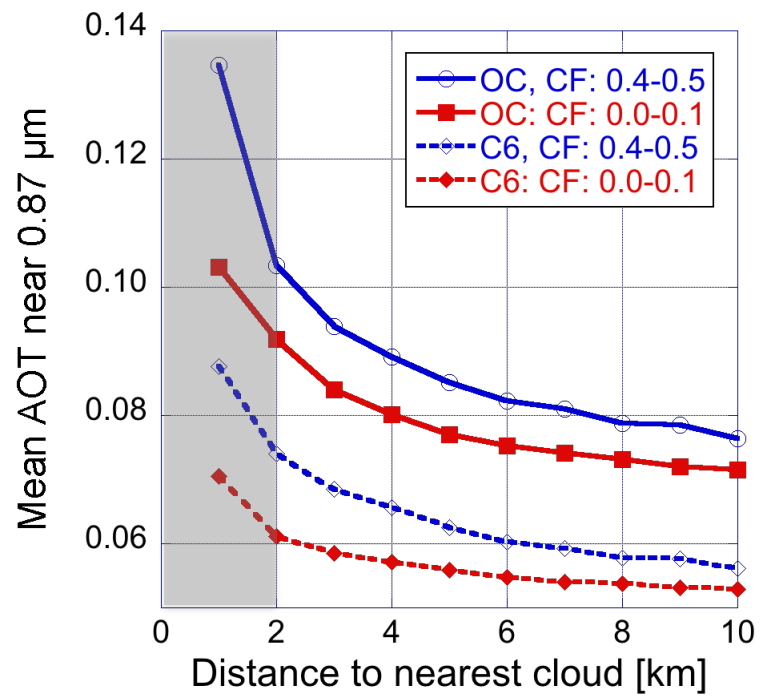
MODIS

(OC products)



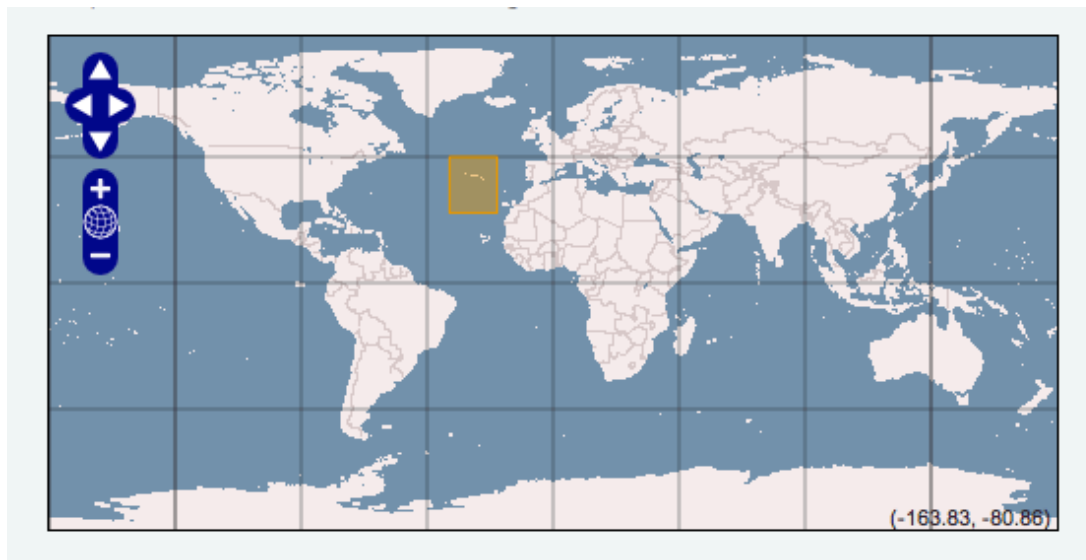
MODIS

(OC and C6 products)



CALIPSO

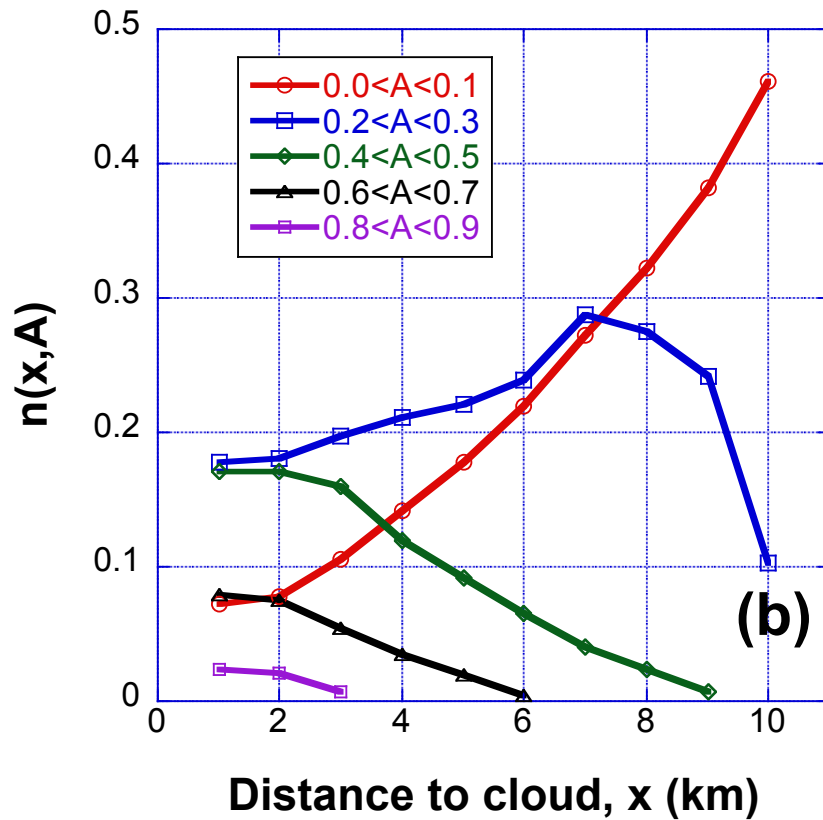
A large region around the Azores



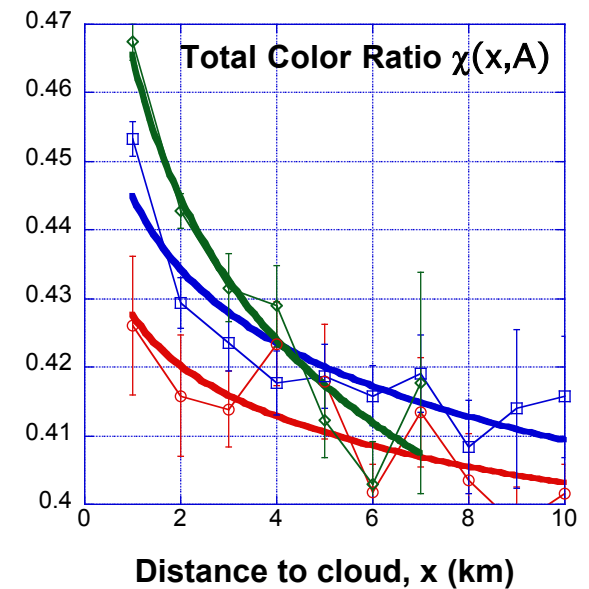
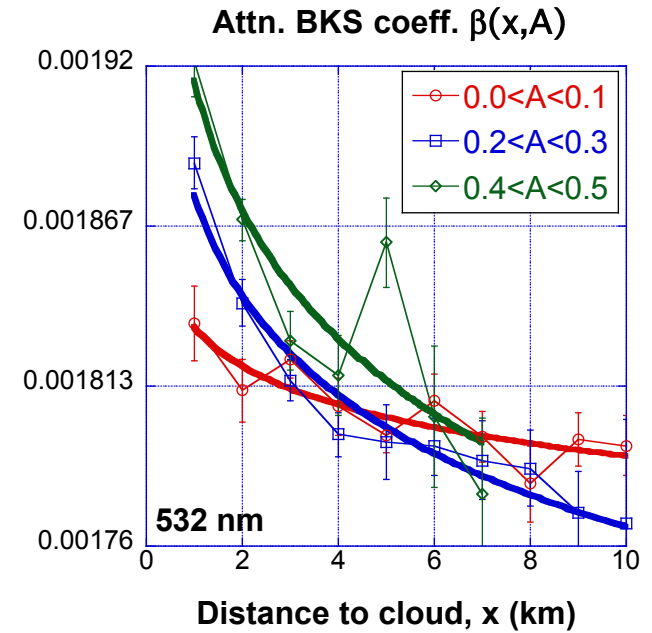
Three year-long observations: 2006.6.21-2009.6.21

CALIPSO

CALIPSO data



Near-cloud enhancements of β and χ occur for any CF but are most pronounced for higher CF

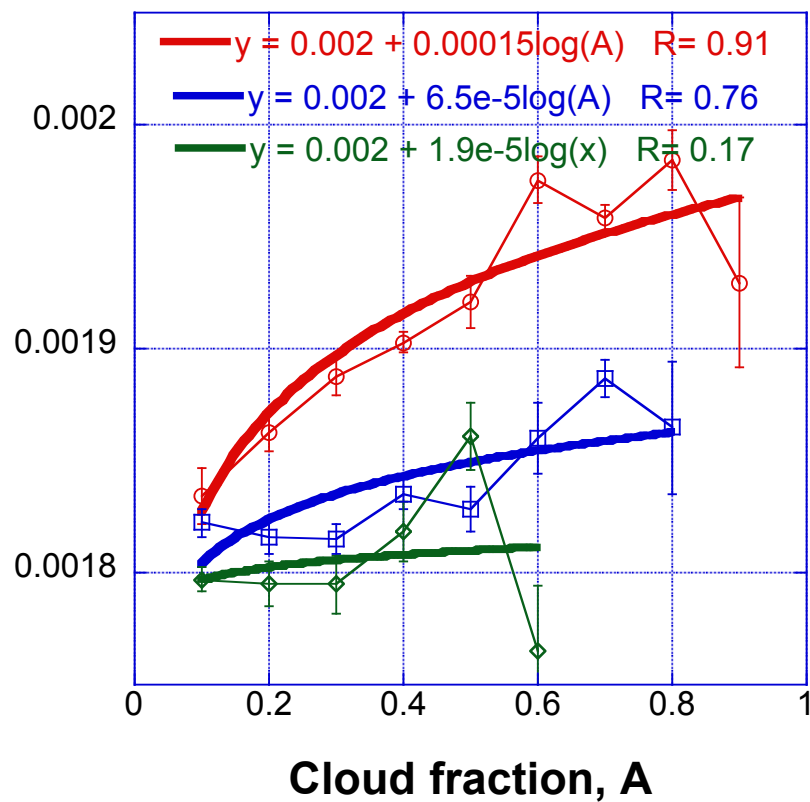


CALIPSO

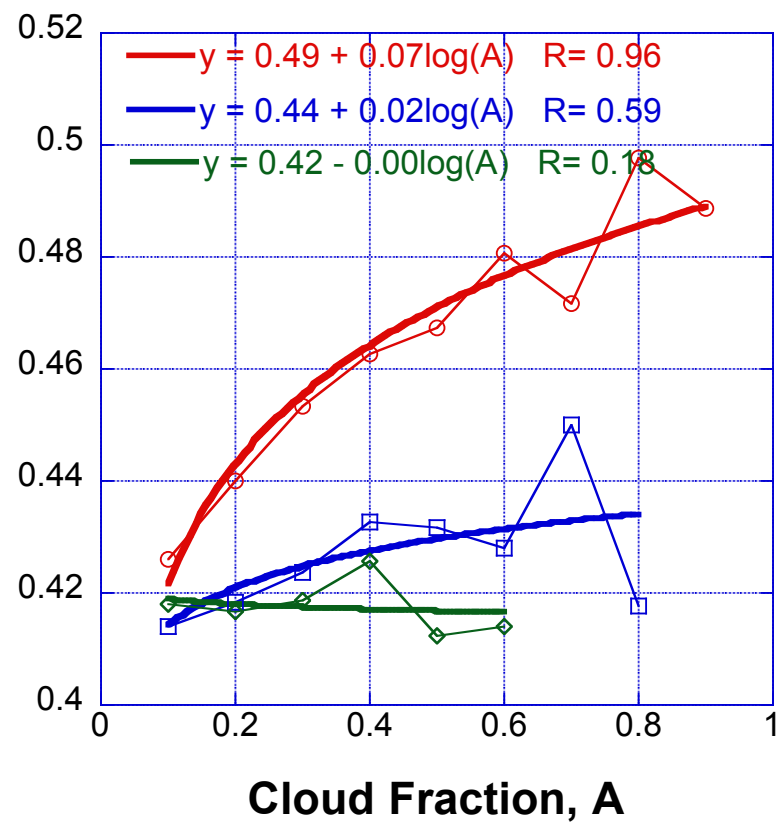
$X =$

- 1 km
- 3 km
- 5 km

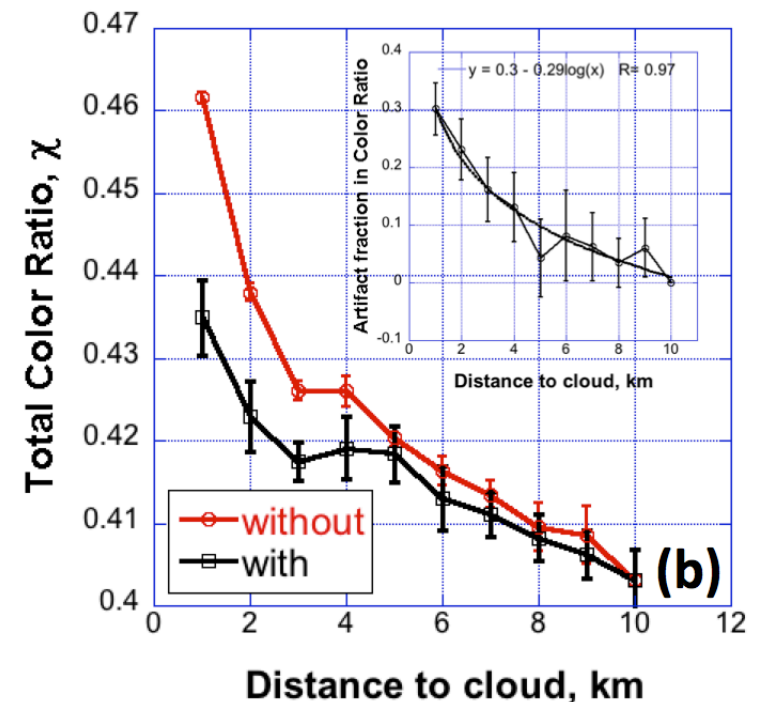
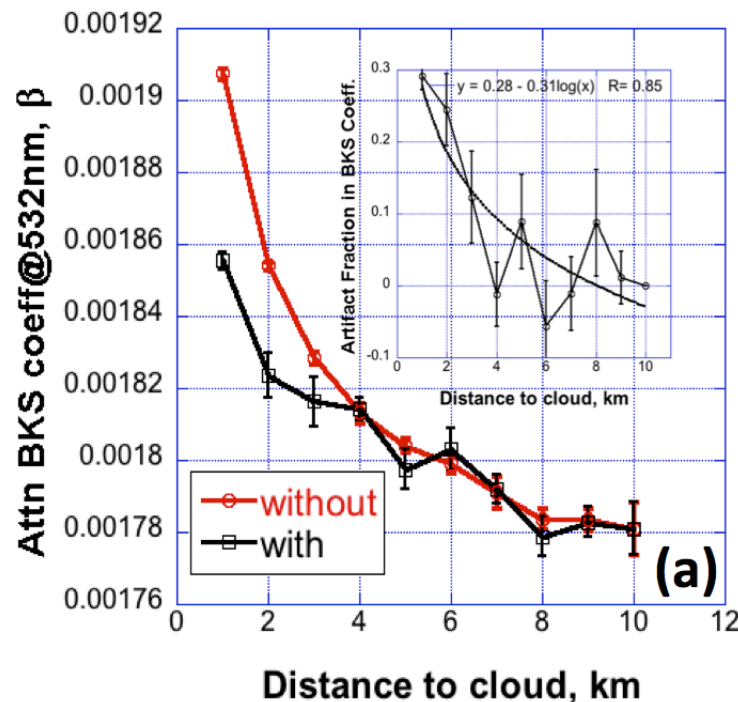
Attn BKS coeff., $\beta(x,A)$



Total color ratio, $\chi(x,A)$



Backscatter and Color Ratio with and without correction



Correction = Resampling:
the distr. of cloud fraction ($n(x,A)$) is the same for any distance to clouds

Take home messages

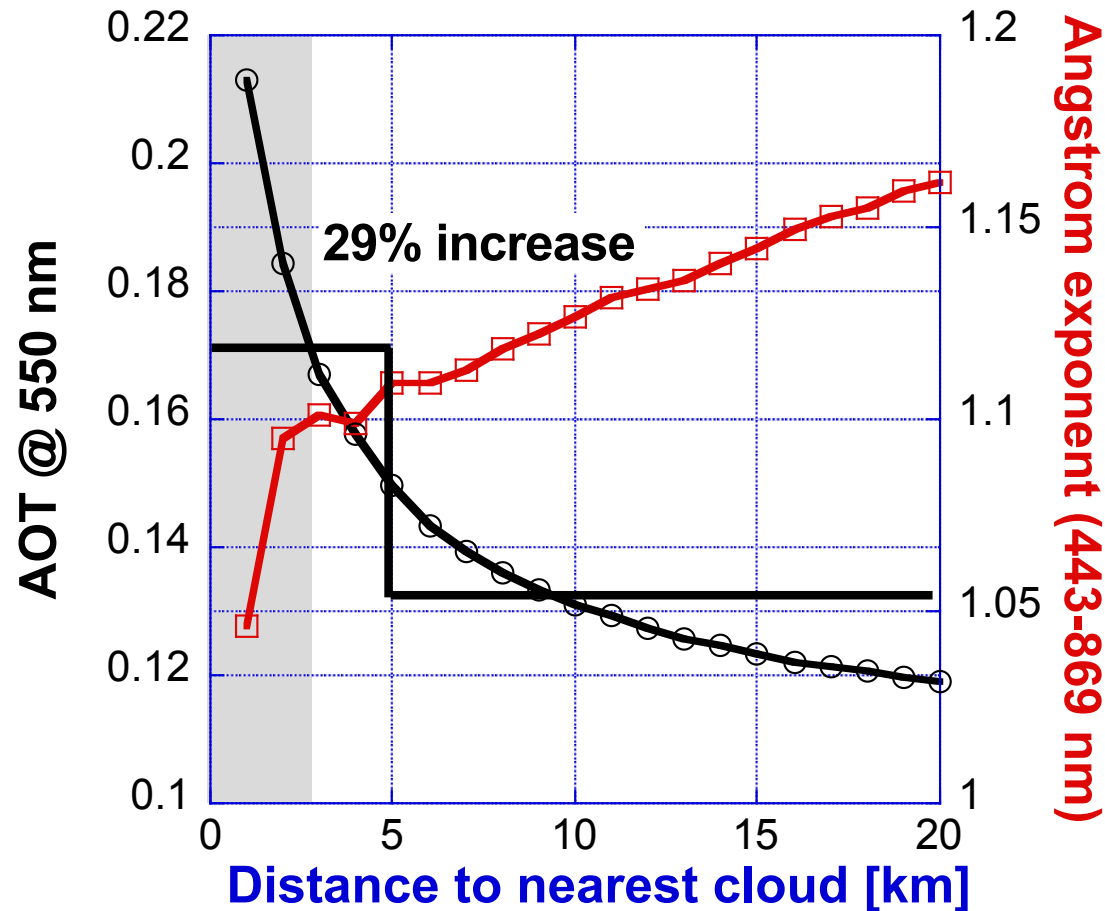
- Aerosol properties (thus radiative forcing) near clouds might be significantly **different** from those far from clouds;
- Remote sensing retrievals near clouds is challenging but **excluding aerosols near clouds** dramatically **reduces** the data volume and **underestimates** the forcing, while **including** them may **overestimate** it;
- Near-cloud aerosol **statistics are dominated** by samples from scenes with **higher cloud fractions**;
- Near-cloud **enhancements** of attenuated backscatter **occur for any cloud fraction** but are most pronounced for higher cloud fractions;
- Near-cloud **enhancements** can be well **approximated** by **logarithmic functions** of cloud fraction and distance to clouds;
- The **sampling issue** explains 15-30% of the near-cloud enhancement.

Acknowledgments:

- NASA Radiation Sciences Program;
- NASA CALIPSO/CloudSat Project;

Thank you!

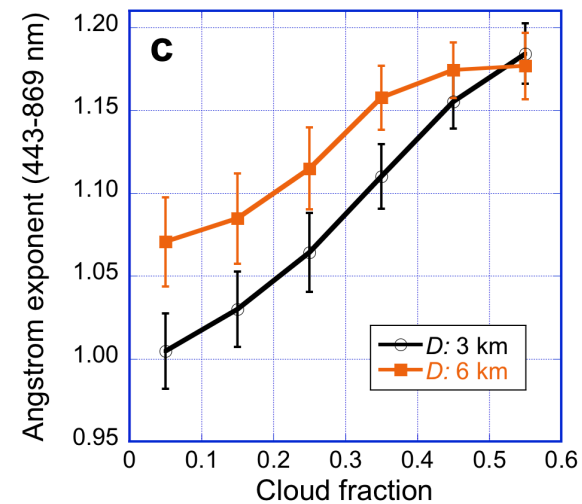
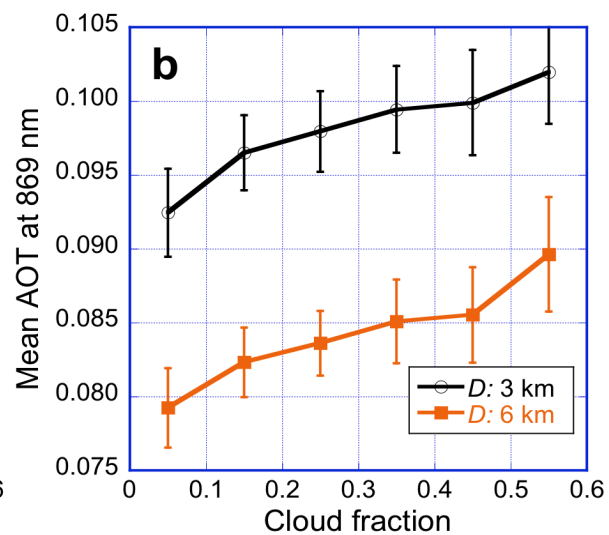
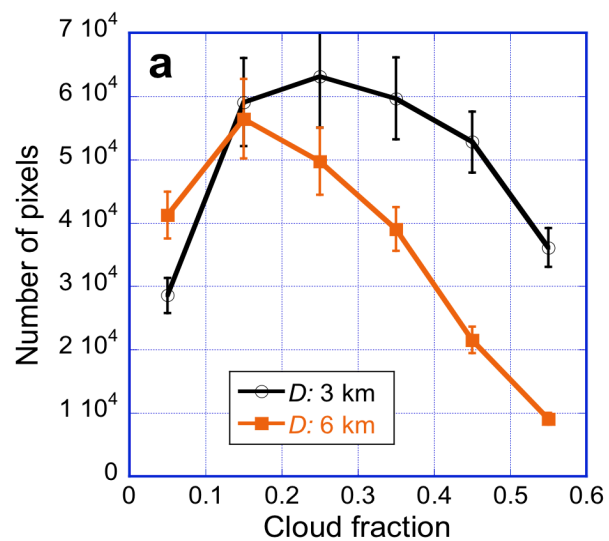
Aerosol Properties in MODIS ocean product



Aqua, Northeast Atlantic, September 14-29, 2002-2011

MODIS

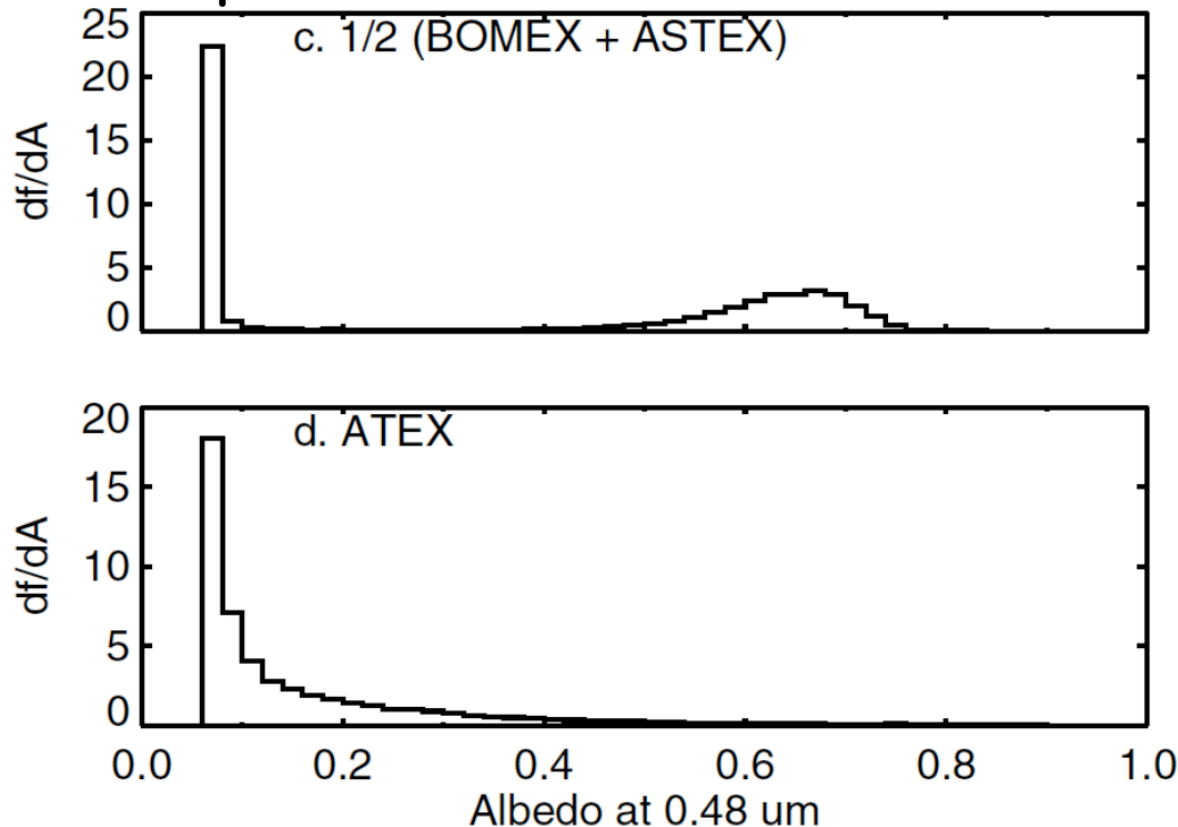
(OC products)



Inseparability of cloudy and clear skies under partial cloud cover

(from Charlson et al., 2007)

Albedo pdfs from LES of trade Cu and Sc clouds



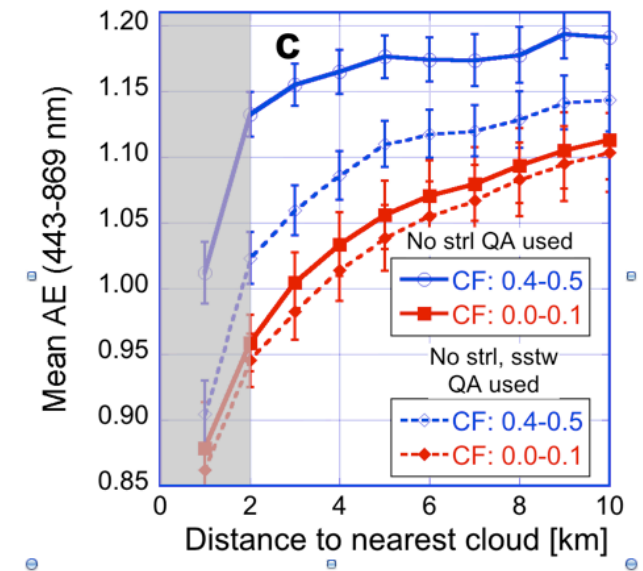
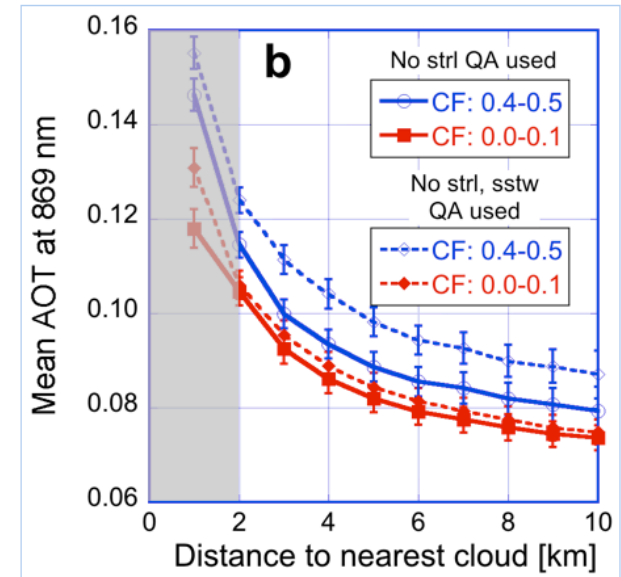
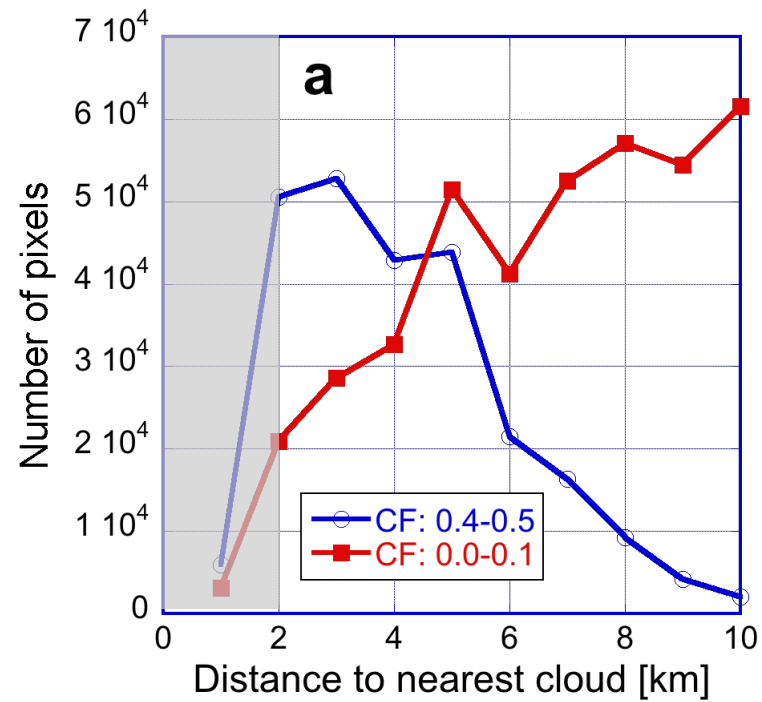
average of the BOMEX (~10% cloud cover) and ASTEX (overcast) fields; clear and cloudy contributions are nicely separated

for ATEX trade Cu (~50% cloud cover), with the albedos from clear and cloudy portions inseparable

"The existence of partly cloudy regions and the fact that the clear-cloudy distinction is ambiguous and aerosol dependent raise the possibility that the conventional expression may lead to errors." (Charlson et al., 2007)

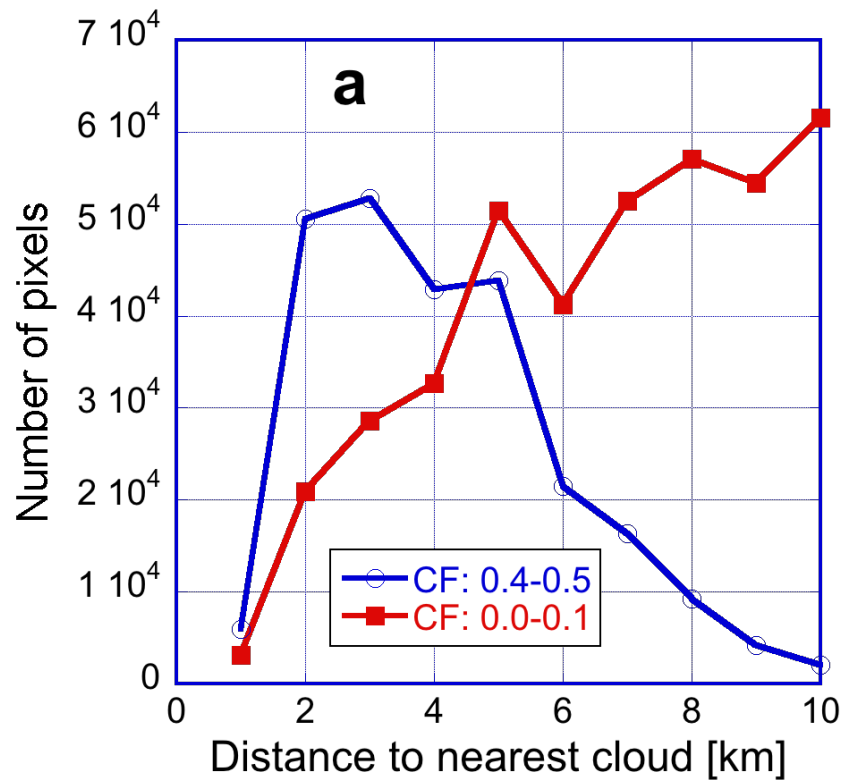
MODIS

(OC products)

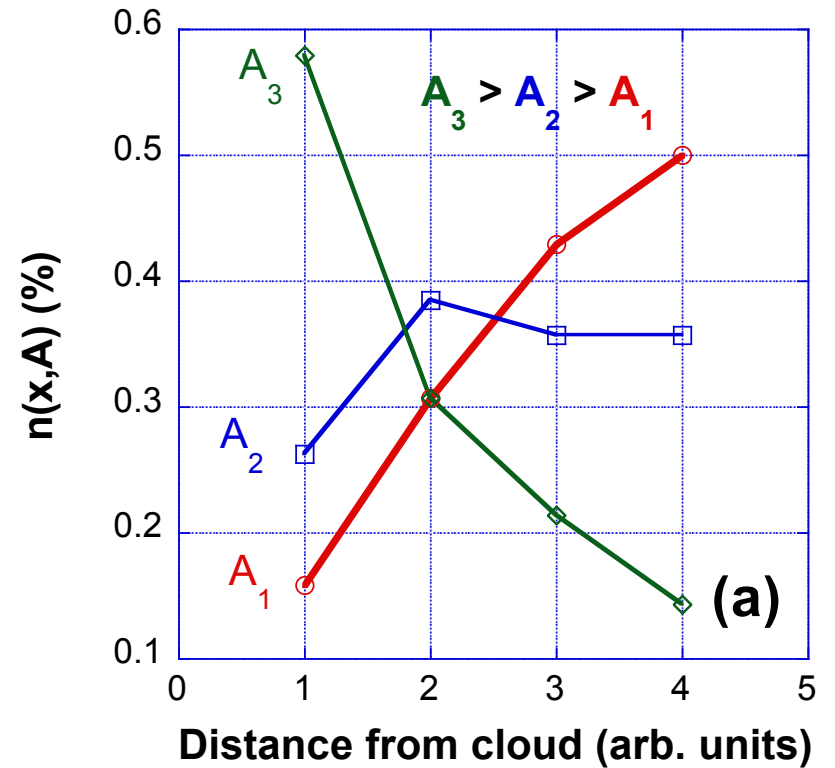


MODIS

MODIS data



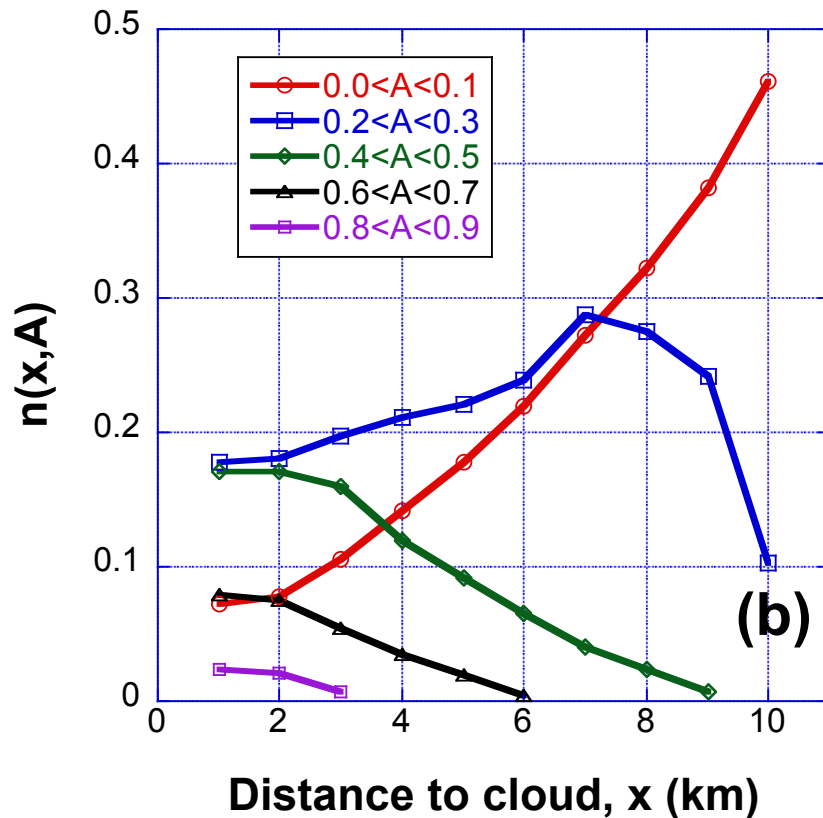
Schematic plot



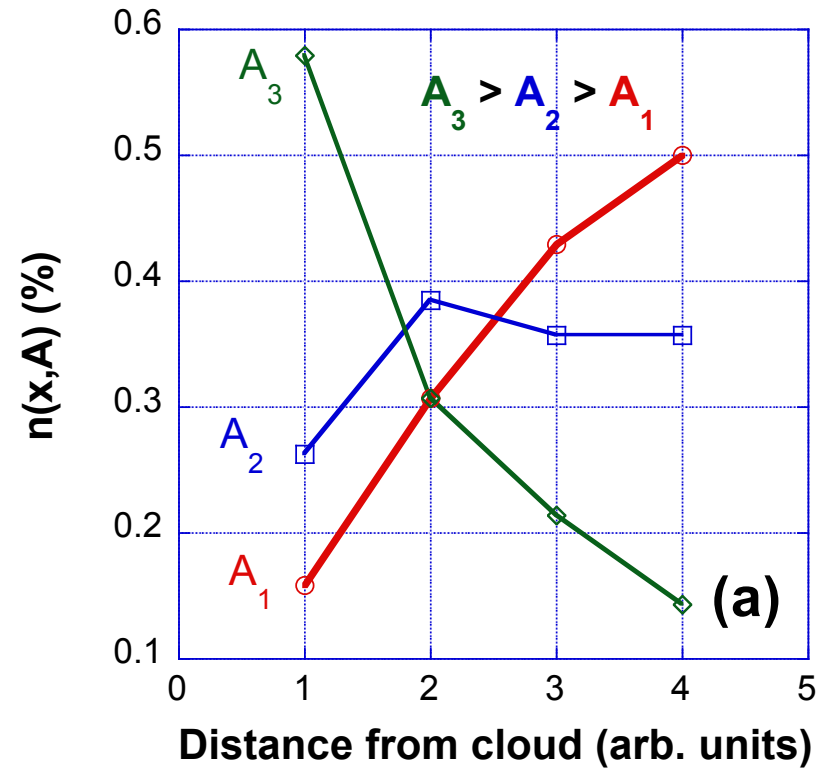
Near-cloud aerosol statistics are dominated by samples from scenes with higher cloud fractions

CALIPSO

CALIPSO data



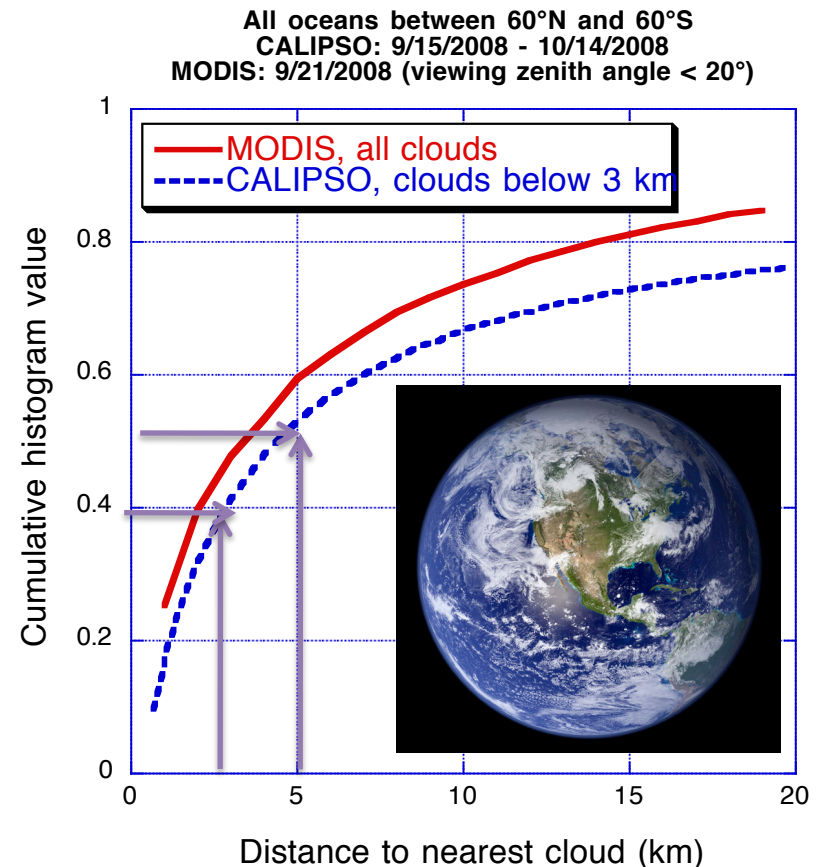
Schematic plot



Near-cloud aerosol statistics are dominated by samples from scenes with higher cloud fractions

Motivation

- Climate studies (e.g., aerosol indirect effect) demand a precise **separation of clear and cloudy** air;
- Remote sensing **retrieval** of aerosol properties near clouds is a big **challenge**;
- Excluding aerosols near clouds will dramatically reduce the database and **underestimate** the forcing, while including them may **overestimate** it because of unaccounted cloud contamination.



from **MODIS**: 60% of all clear sky pixels are located 5 km or less from all clouds
from **CALIPSO**: 50% of all clear sky pixels are located 5 km or less from low clouds